In the Wake of a Tidal Turbine

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Work stream 4: Arrays, wakes and near field effects

Introduction

An understanding of the behaviour of the wakes of tidal turbines is a key area in the future development of the technology. Array layout will be determined (at least in part) by wake/device interaction, and environmental issues such as seabed scouring and bathymetric alterations may be brought on by the wake.

Current understanding of tidal turbine wakes is constrained by several factors. Full scale testing is prohibitively expensive for most, and usually commercially sensitive. Simulation tools have been used extensively, but often with limited accuracy unless validated. A certain amount of cross over from the wind industry is possible, but there are significant differences in the turbulence structures and the existence of a free surface. With this in mind, this project seeks to achieve a data set using scale testing.

Methodology

Two devices [Figure 1] have been tested in a re-circulating flume tank, 35 m long, 92 cm wide and 70 cm high. The head and flow speed are set (to 40 cm and 40 cm/s) by adjusting the sluice gate and pump speed. The Phase One turbine is a 2 blade, 25 cm diameter, rotor attached to a dc motor, housed in a plastic nacelle, mounted on a gravity anchored monopile. The Phase Two turbine is a 'floating' (i.e. suspended) device of 30 cm diameter capable of two, three and contra-rotating blade configurations, as well as variable pitch settings. Measurements are taken with a 25 Hz Acoustic Doppler Velocimeter, using a grid based system. At different points downstream measurements are taken, both for the wake and the empty flume. These are then normalised and presented.

Figure 1: Phase one and two experimental setup

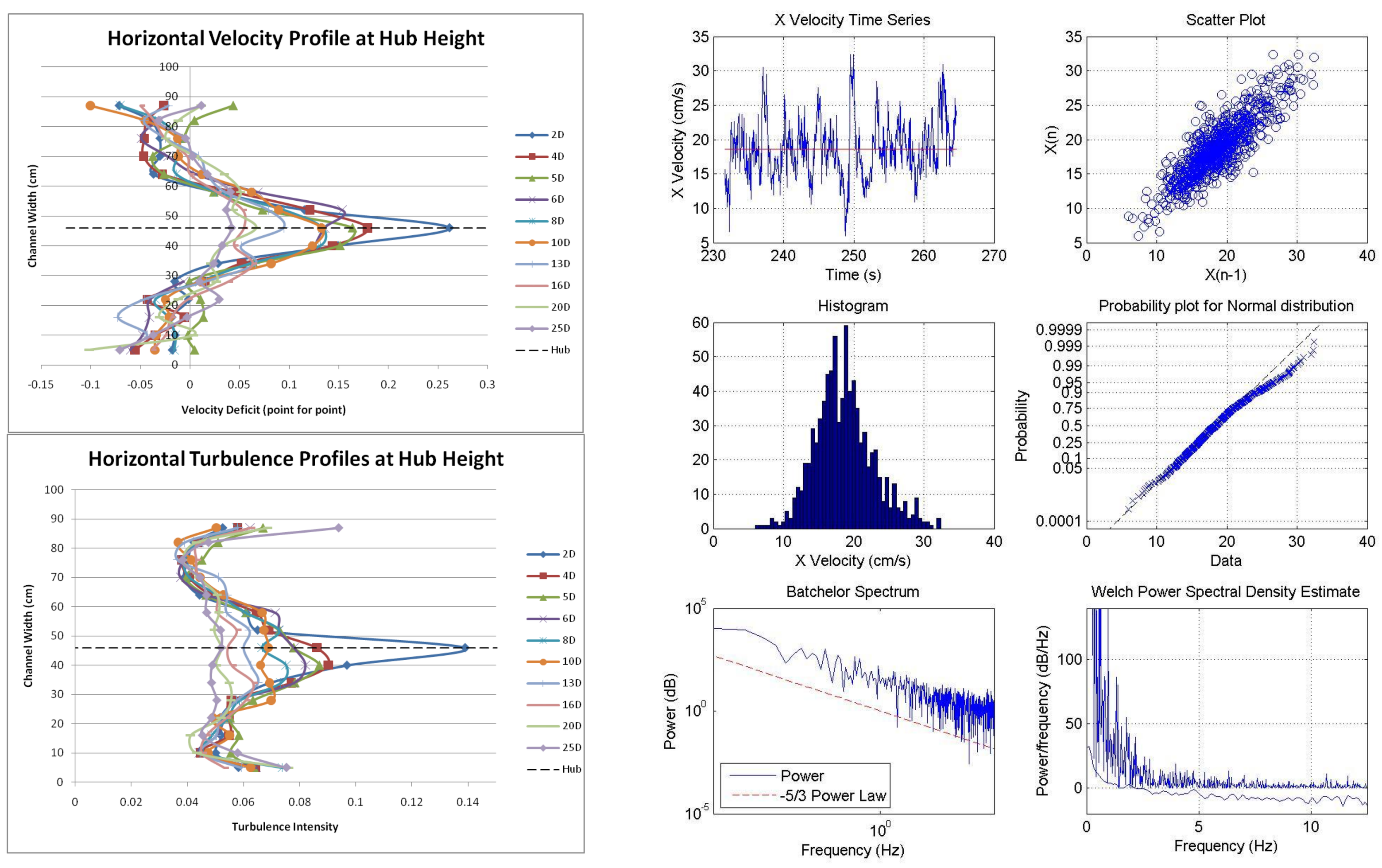

Figure 2: Velocity and turbulence profiles in the wake of the Phase One Device, and a six plot analysis of a point directly behind the Phase Two Device

Some Results

Figure 2, above left, shows the effect of the turbine on the velocity and turbulence in the flow. Immediately behind the turbine the wake can be seen in the form of a large velocity deficit. As distance downstream increases the deficit decreases, until it drops below 5%. This occurs around 20D downstream, considerably further than some literature might suggest. From these graphs it would appear that the turbulence dissipates before the velocity deficit, contradicting current knowledge. However, a likely explanation is that the turbulence is still present, but with its energy mainly concentrated in eddies exceeding the frequency of the measuring equipment.

Further analysis of the data series corresponding to a single point gives visual guidance regarding certain properties [Figure 2, right]. These plots correspond to a data point immediately downstream of a Phase Two device. A time series and scatter plot show velocity fluctuations and consistency. The histogram and probability plot indicate skew, kurtosis and normality. The Batchelor spectrum shows the energy cascade in the frequency domain, compared with the theoretical prediction. A Fourier transform highlights energy peaks at different frequencies, corresponding to the blade shadowing (1 Hz).

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